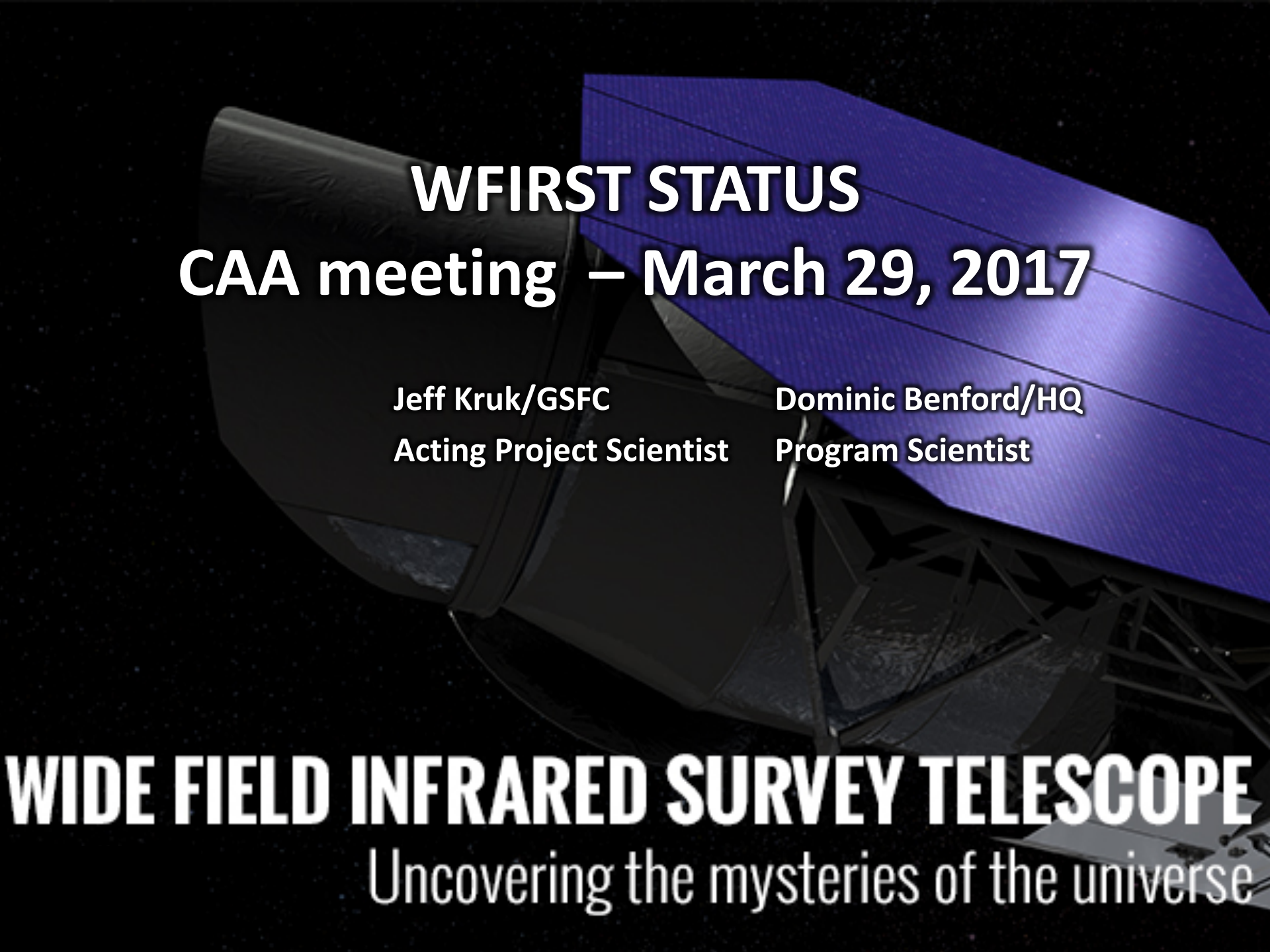
WFIRST STATUS
CAA meeting – March 29, 2017
Jeff Kruk/GSFC
Acting Project Scientist
Dominic Benford/HQ
Program Scientist
WIDE FIELD INFRARED SURVEY TELESCOPE
Uncovering the mysteries of the universe


WFIRST
WIDE-FIELD INFRARED SURVEY TELESCOPE
ASTROPHYSICS • DARK ENERGY • EXOPLANETS

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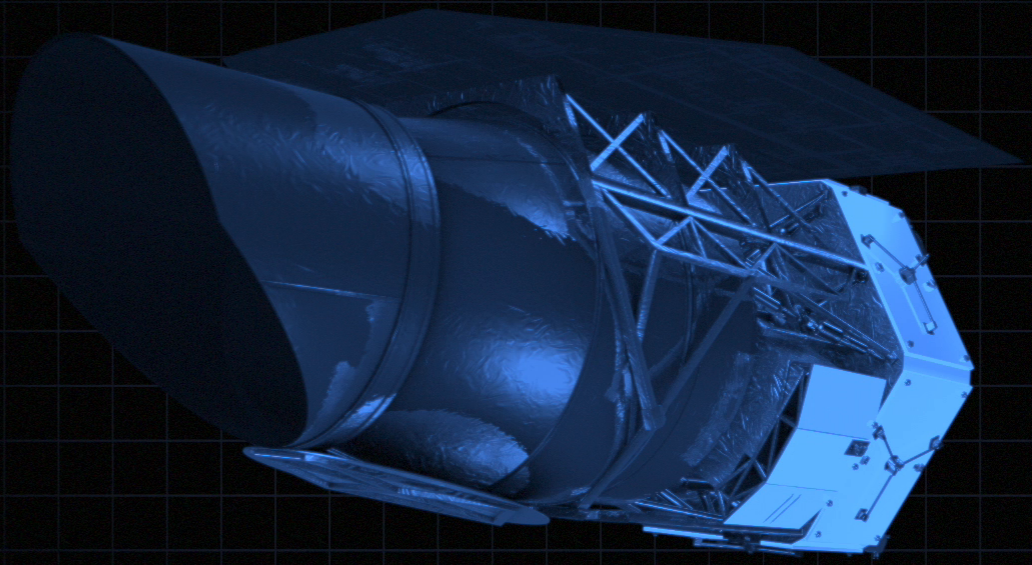


Outline

Programmatic Elements (Dominic Benford)

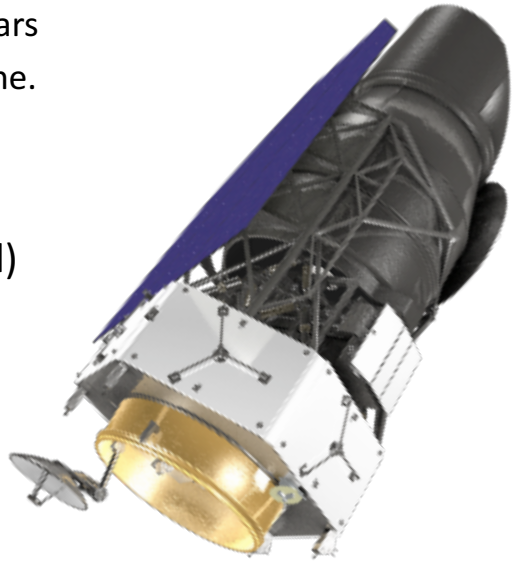
- Mission schedule
- Response to mid-decadal study recommendations
- Cost estimation & cost control
- Starshade Compatibility Study

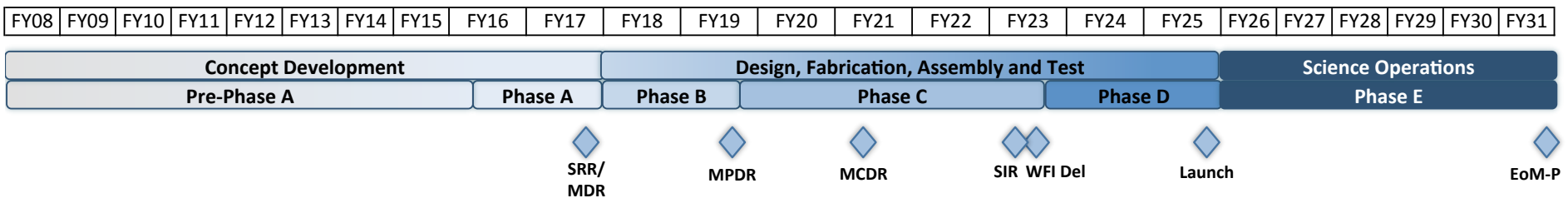
Mission Status Update (Jeff Kruk)

- Technology Development
  - NIR detectors
  - Coronagraph
- Key changes since prior presentations
- Telescope status
- Instrument & science status

Basic Facts

- **Objectives:**
  - Characterize the history of cosmic acceleration and structure growth
  - Understand how planetary systems form and evolve and determine the prevalence of planets in the colder outer regions
  - Understand the compositions and atmospheric constituents of a variety of planets around nearby stars and to determine the properties of debris disks around nearby stars
  - A peer-reviewed Guest Observer program allocated 25% of mission time.
- **Mission Duration:** 6 ¼ years
- **Orbit:** Sun-Earth L2
- **Ground Stations:** Near Earth Network (Ka-band, S-band)
- **Space Network:** S-band for launch
- **Ground System:** MOC/Science Center/IOC
- **Launch Vehicle:** Delta IV Heavy or Falcon Heavy
- **Launch Site:** Eastern Range





Schedule Milestones

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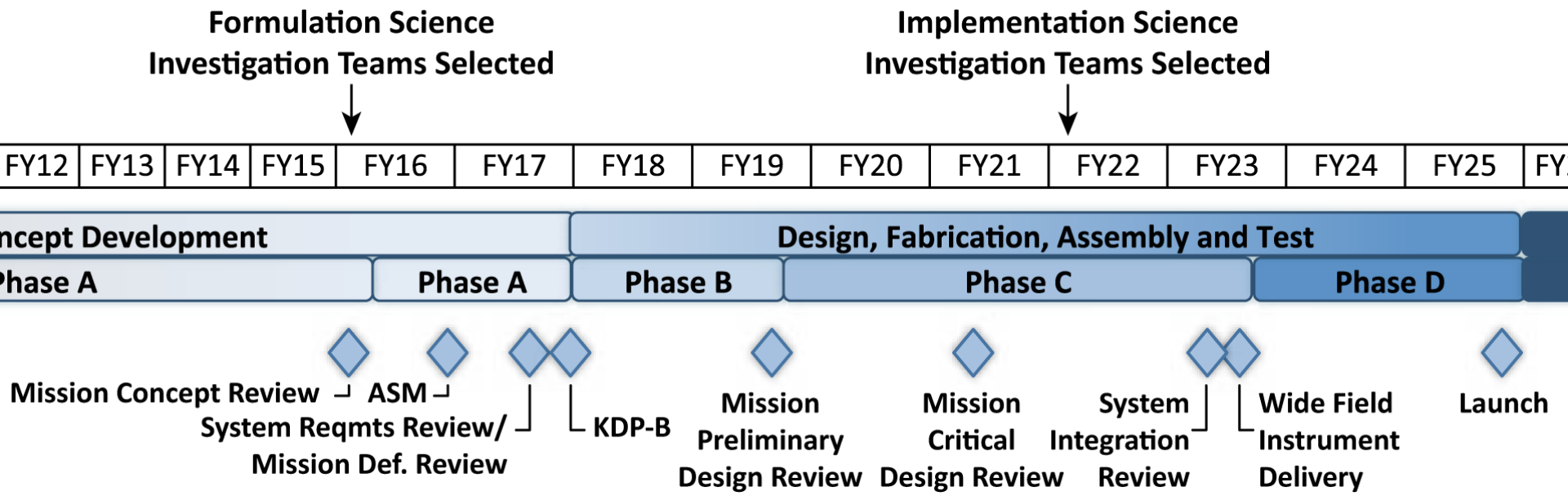
✓	Mission Concept Review	2015 Dec 8-9	•	MPDR	2019 Apr 29
✓	SIT selection	2015 Dec 17	•	KDP-C (Phase C start)	2019 May 29
✓	KDP-A (Phase A start)	2016 Feb 17	•	MCDR	2021 Jan 4
✓	Acquisition Strategy Meeting	2016 Aug 18	•	KDP-D (Phase D start)	2023 Nov 15
•	SRR/MDR	2017 Jul 11-13	•	Launch Readiness Date	2025 Sep 5
•	KDP-B (Phase B start)	2017 Oct 1			



Midterm Assessment Report

- "At the currently estimated cost, NASA's decision to add a coronagraph to … WFIRST is justifiable within the scientific goals of NWNH. The broader societal interest in the possibility of life beyond Earth is also compelling. However, an increase in cost much beyond the currently estimated $350 million would significantly distort the science priorities set forth by NWNH." (Finding 4-4)
- "Prior to KDP-B, NASA should commission an independent technical, management, and cost assessment of WFIRST, including a quantitative assessment of the incremental cost of the coronagraph. If the mission cost estimate exceeds the point at which executing the mission would compromise the scientific priorities and the balanced astrophysics program recommended by [NWNH], then NASA should descope the mission to restore the scientific priorities and program balance by reducing the mission cost." (Recommendation 4-1)

NASA Initial Response:

- NASA plans to conduct an independent Technical, Management, Cost assessment of WFIRST prior to KDP-B.
- NASA will manage WFIRST and the overall astrophysics portfolio to maintain program balance.

Cost 1. Assessment

"Commission an independent technical, management, and cost assessment"

- Will conduct two internal cost assessments (one at GSFC's independent cost estimator, one at JPL where the ExEP Program is based) – in addition to Project's own grassroots estimate.
- Will conduct two independent external cost/technical assessments (Aerospace Corporation & the Standing Review Board)
  - Data provided in May/June timeframe, and Aerospace will be present at the System Requirements Review / Mission Definition Review in July
  - Analysis first look presented in August, followed by reconciliation.
  - Independent cost estimates to be factored in to NASA decision to proceed to KDP-B
- Four technical, management, cost estimates provided by independent groups, two of which are external to NASA.

Cost 2. Control

"If the mission cost estimate exceeds [something] … then NASA should descope the mission to restore the scientific priorities and program balance by reducing the mission cost."

- At KDP-A (February 2016), NASA established a management agreement with WFIRST. "estimated total mission cost will be a KDP-B success criterion."
- Total mission cost for success allocated to $3.2B in real year funds
  - Equivalent to $2.7B in FY15 or $2.4B in FY10
  - Includes coronagraph (~$0.4B) and GO support (~$0.1B) and launch vehicle, but not starshade-readiness
- Grassroots cost estimate being done now for the first time (previously only parametric); estimate soon from different methodology
- Will reduce aspects of WFIRST to control cost, but maintain scientific capabilities necessary to retain compelling value

Cost 3. Coronagraph

"an increase in cost [of the coronagraph] much beyond the currently estimated $350 million would significantly distort the science priorities"

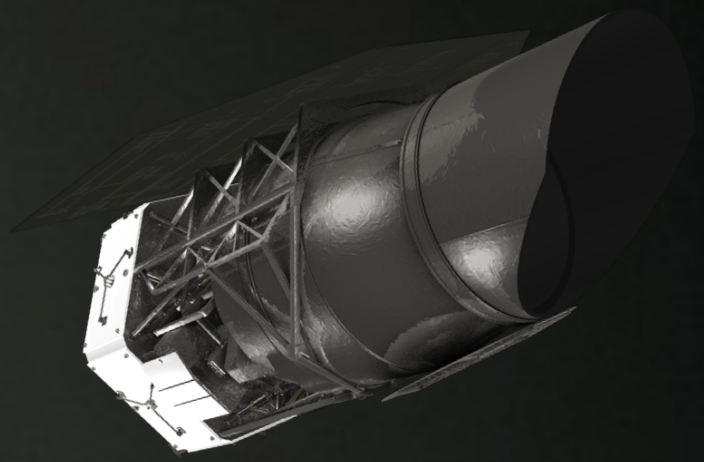
- While WFIRST mission risk category is Class B (e.g., Spitzer, Fermi, Kepler), the coronagraph is being designated as Class C (e.g. Explorer missions).
- Current specified requirements on scientific performance intended to drive compelling exoplanet observation capabilities in direct imaging and spectroscopy, but will be revisited if necessary to control cost.
- Continued technology improvement will be allowed up through CDR to incorporate best possible capability.

Starshade Compatibility

- **WFIRST does not have a starshade; studying accommodating one for next Decadal Survey's consideration.**
- **HQ directed WFIRST to conduct a study of starshade compatibility, June 2016**
  - Starshade compatibility is to be included into Phase A design reference mission
  - Required functionality shall be incorporated in the starshade system rather than in WFIRST, wherever possible
  - Final assessment at SRR/MDR by ExEP & SRB, SMD to decide in/out at KDP-B
- **Preliminary assessment presented Dec 12 2016; direction was to proceed with study, with following guidance:**
  - Do not consider on-board orbit determination (do from ground)
  - Minimize spending prior to announcement of Decadal recommendation regarding a starshade mission
- **Science benefit: starshade permits detection and characterization of HZ Earths and super-Earths, plus whole-system imaging – extending reach of WFIRST exoplanet discoveries**

Leadership Change

Neil Gehrels (1952-2017)



WFIRST Project Scientist Neil Gehrels died February 2017

Anticipate selection of new Project Scientist by GSFC & HQ this summer

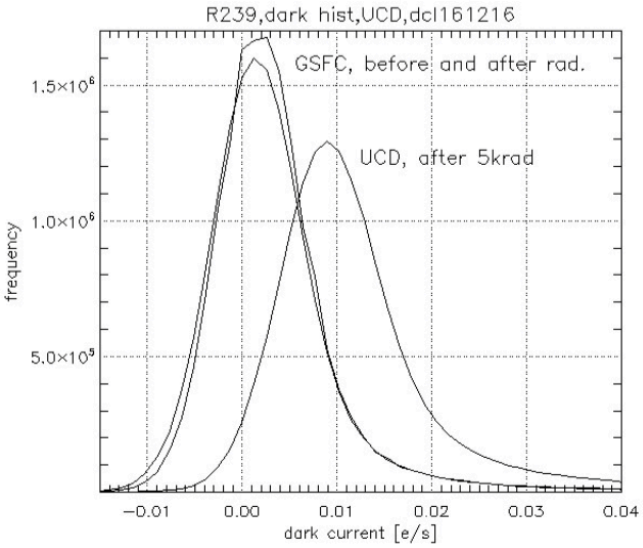
Technology Development

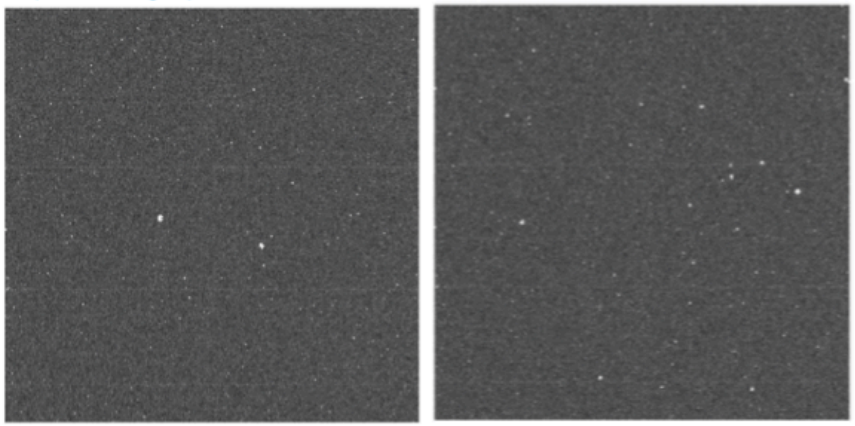
- WFIRST has been supporting a three-year directed technology development effort
  - Started in February 2014, focused on infrared detectors & coronagraph
  - Independent technology assessment committee reviewed milestones.
- WFIRST successfully completed its early technology development phase in January 2017
  - Milestone reports are available online at https://wfirst.gsfc.nasa.gov/library.html.
- WFIRST has addressed its top technical risks.
  - Aerospace Corp. technical concern on maturity of H4RG detectors. ✔☐
  - Harrison report, 2014: "Recommendation 2-1: NASA should move aggressively to mature the coronagraph design" ✔☐

NIR Detector Status

- WFI Detector TAC milestone 5 passed 1/17/17
  - "Complete environmental testing (vibration, radiation, thermal cycling) of one SCA sample part, as per NASA test standards"
  - SCA 18237 cycled thermally, vibrated, retested; no significant performance changes
  - SCA 18239 exposed to protons to 5 krad at UC Davis; some mild degradation to (e.g..) dark and persistence, but in family with prior testing of HxRG family devices
- Infrared detectors (Teledyne H4RG arrays) have completed all necessary testing for the space flight environment. Maturity equivalent to TRL=6.
- State-of-the-art performance: typical quantum efficiencies in excess of 90%, typical dark currents around 10e-/hr, and typical read noise level of 15e- (CDS)
- Detectors from final yield demonstration lot now coming in
  - Final choice of design parameters when evaluation of this lot is complete (will then be ready for flight procurement)
  - Process improvements have led to steady increases in yield

Detector Characterization





Pre-rad (Davis)
16.8 e

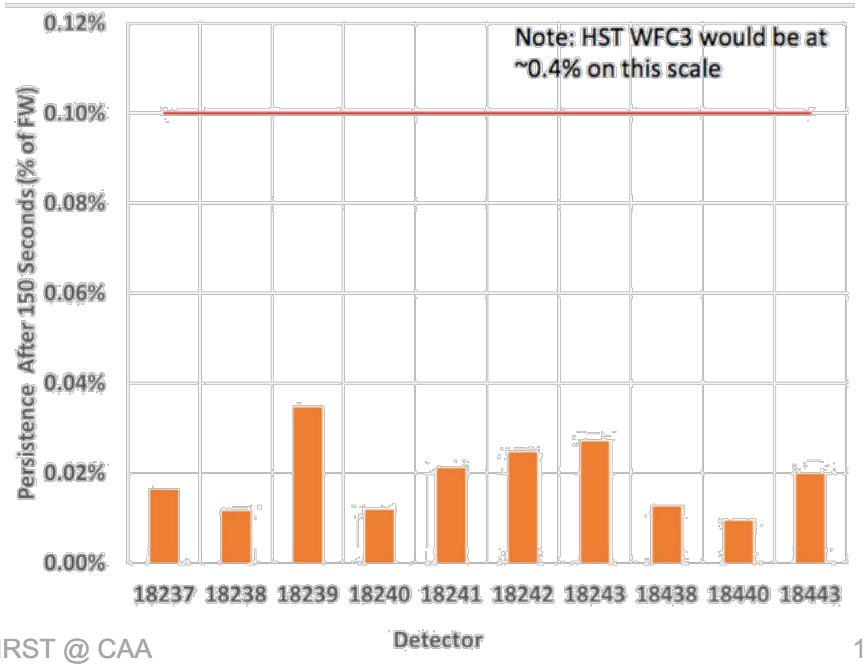
Post-rad (Davis)
16.9 e

Above: dark current unchanged with radiation testing

Top Right: read noise unchanged with radiation testing

Lower Right: Persistence reliably exceeds requirements

Persistence Summary at 100K, 1.0V

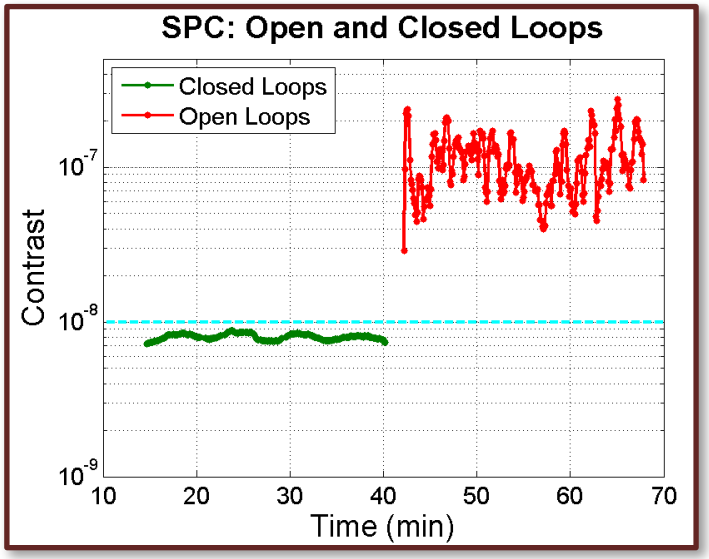


Coronagraph Technology Status

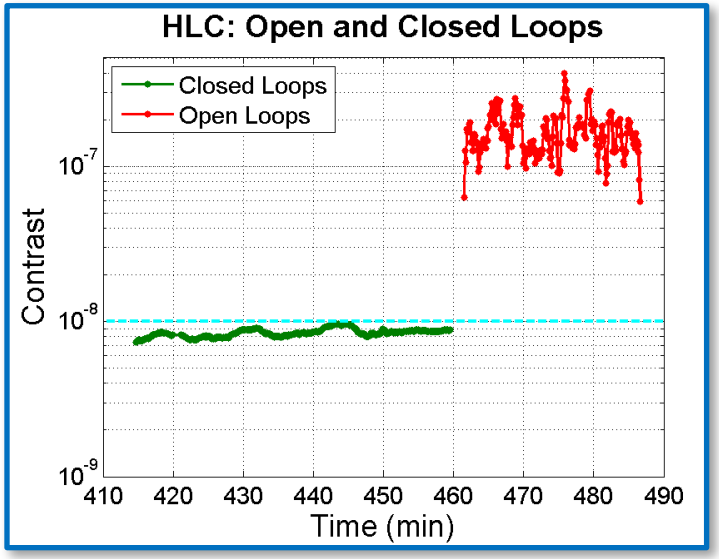
- CGI TAC milestone 9 passed 1/27/17
  - "Occulting Mask Coronagraph in the HCIT demonstrates 10-8 contrast with 10% broadband light centered at 550 nm in a simulated dynamic environment"
  - Both Shaped Pupil and Hybrid Lyot configurations, demonstrated to have sum of static contrast plus residual of closed loops for relevant WFIRST levels of tip/tilt (jitter plus drift) and focus errors below 10-8
- Coronagraph technology development has demonstrated full system level performance In a simulated WFIRST dynamic environment, equal to TRL-5
- A raw contrast of better than 10^{-8} was achieved by the hybrid Lyot and shaped pupil architecture using low-order wavefront sensing and control to correct for the simulated disturbances
- Report is available at: https://wfirst.gsfc.nasa.gov/newsroom.html

Coronagraph Milestone 9 results

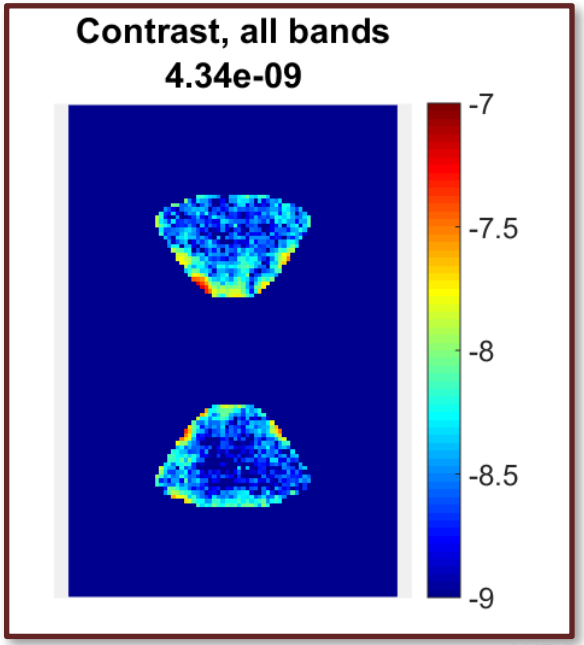
SPC Dynamic Test



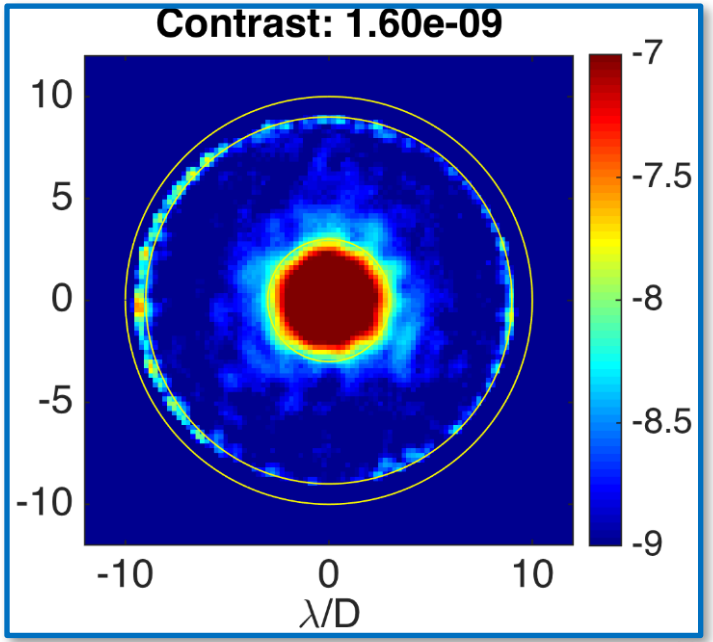
HLC Dynamic Test



Best SPC Static Contrast



Best HLC Static Contrast



International Partnerships

Pursuing closure on international partnerships for System Requirements Review (July 2017)

- **ESA:**
  - Hardware contribution for instruments
  - Spacecraft contributions
  - Ground station

- **CSA:**
  - Hardware contributions to wide-field instrument (calibration, integral field)

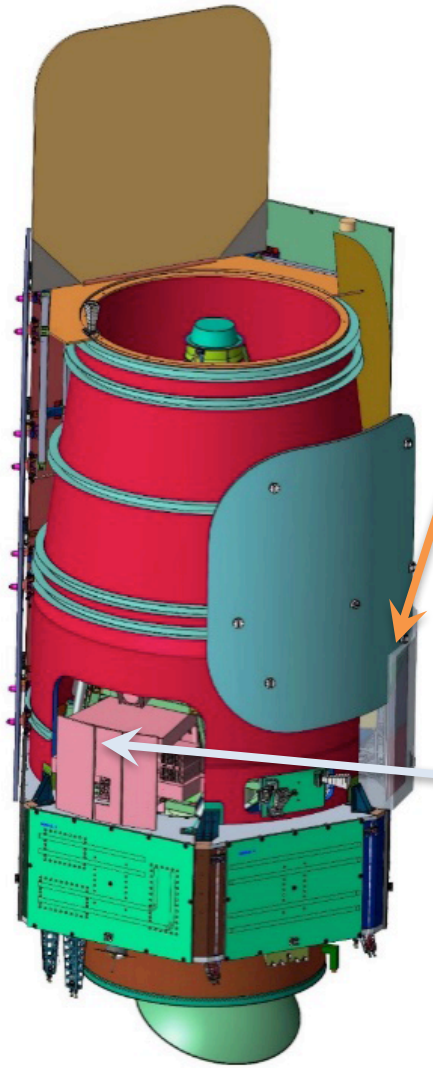
- **JAXA:**
  - Hardware contribution to coronagraph (polarimetry)
  - Ground station
  - Synergistic ground-based telescope time (including Subaru)

- **Australia:**
  - Ground station

Key Changes

- **Telescope temperature reduced to 260K from 284K**
  - Sensitivity for wavelengths beyond 1.7 µm now same as below 1.7µm.
  - Grism bandpass can be extended back to 2.0 µm.
- **Tertiary optics moved from WFI to telescope**
  - Simplifies optical testing during I&T
  - Re-packaging of Wide-field instrument enables larger filter wheel, 10 positions
- **Active vs. Passive Detector Cooling:**
  - Passive cooling removes critical mechanical cryocooler; reduces electrical power
- **Added two reaction wheels**
  - Reduces slew time, increases time between momentum unloads
- **Increased HGA size from 1.2M to 1.8 M**
  - Reduces TWTA power from 180W to ~70W for same data rate
- **Increased WFI detector sampling from 100KHz to 200 KHz**
  - Reduces detector total read noise (average 2X more readouts per downlink frame)

WFIRST Instruments



Wide Field Instrument

- *Imaging & spectroscopy over 1000s of sq. deg.*
- *Monitoring of SN and microlensing fields*
- Near infrared bandpass
- Field of view 100 x HST and JWST
- 18 H4RG detectors (288 Mpixels)

Coronagraph

- *Image and spectra of exoplanets from super-Earths to giants*
- *Images of debris disks*
- Visible bandpass
- Contrast of 10^{-9} or better
- Exoplanet images from 0.1 to 1.0 arcsec

Filter Suite

Wide-Field Instrument:

Band	Wavelength	Width
R062	0.62µm	0.28µm
Z087	0.87µm	0.22µm
Y106	1.06µm	0.27µm
J129	1.29µm	0.32µm
H158	1.58µm	0.39µm
F184	1.84µm	0.32µm
Wide	1.49µm	1.03µm
Grism	1.45µm	0.89µm
Dark	–	–

Coronagraph:

Band	Wavelength	Width
CGI1 - Rayleigh	0.465µm	0.047µm
CGI2 - Rayleigh	0.565µm	0.057µm
CGI3 – CH_4	0.660µm	0.119µm
CGI4 – CH_4	0.770µm	0.139µm
CGI5 – CH_4	0.890µm	0.160µm
CGI6	0.661µm	0.066µm
CGI7 – CH_4 abs	0.883µm	0.044µm
CGI8	0.721µm	0.036µm
CGI9	0.950µm	0.057µm

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Telescope

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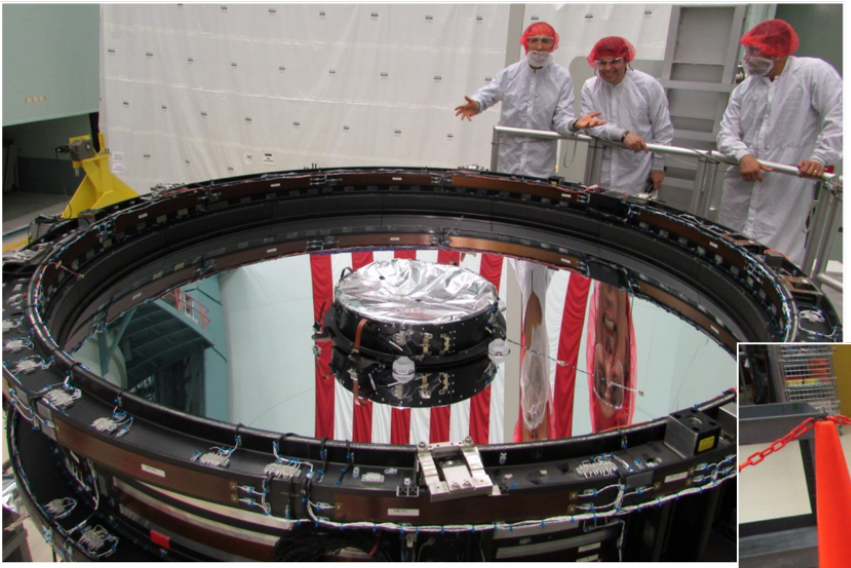
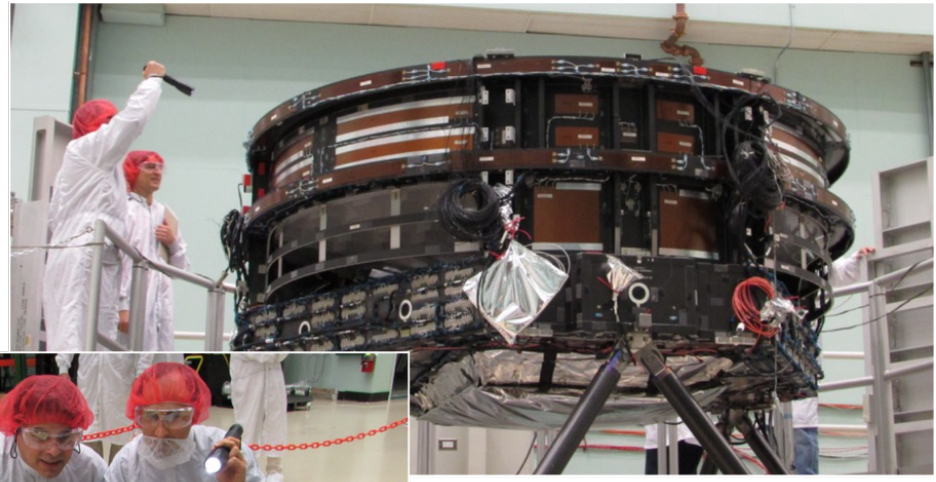
Telescope Status





OTA Pedigree Review Process

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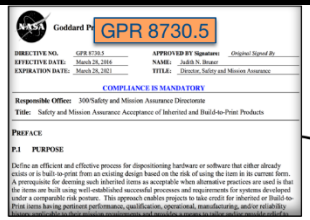
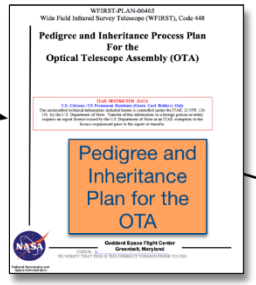
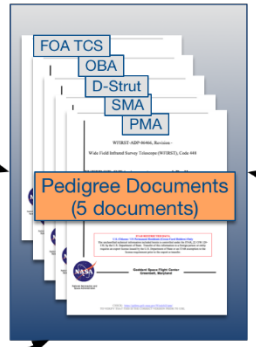
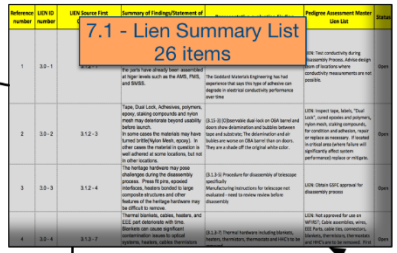


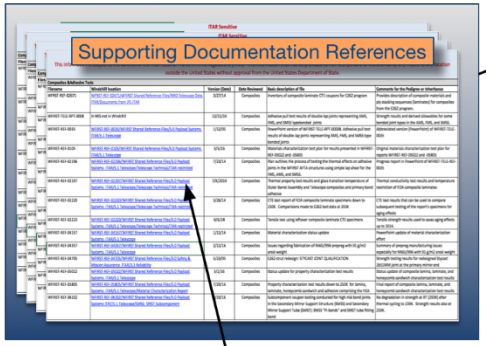


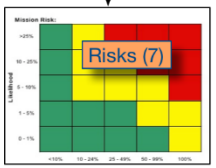


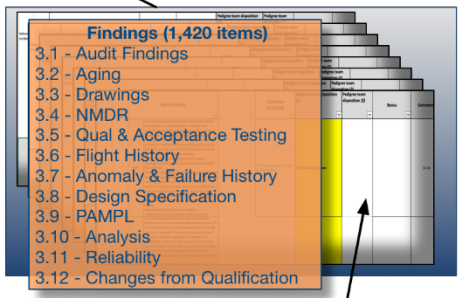


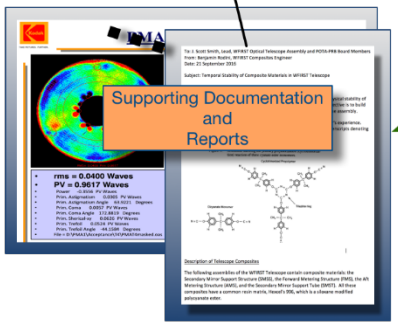
11,018 artifacts reviewed

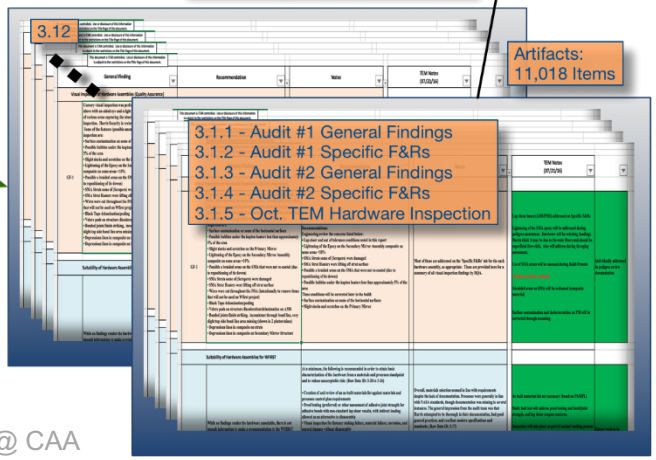
"Risks… of utilizing inherited hardware" (Harrison report, 2014) have been mitigated.





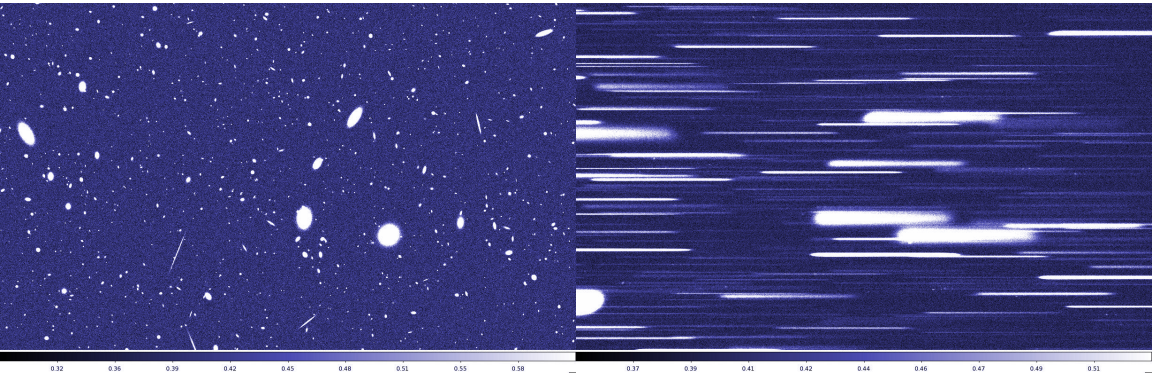






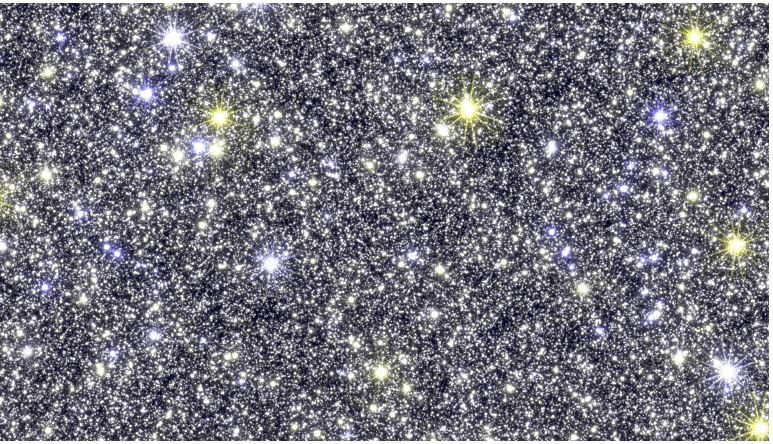
Simulations Status

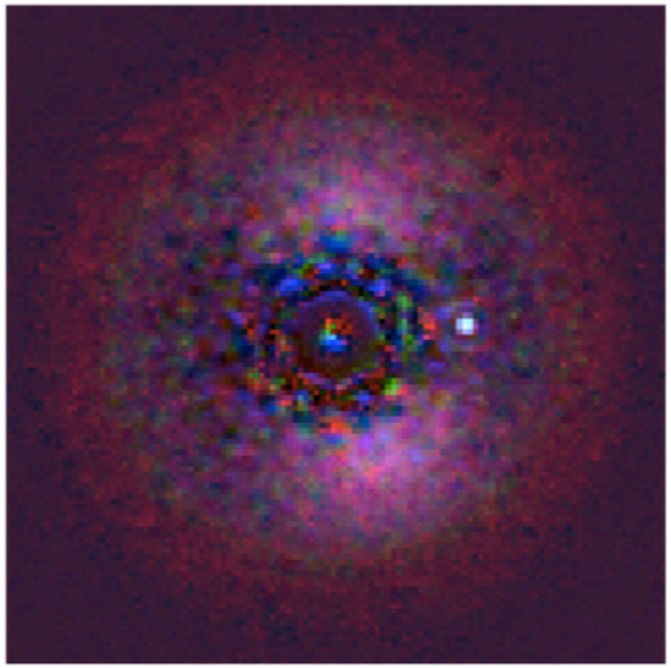
WFIRST Simulations for all science now operational;
working on detailed assessments supporting design efforts



Above: Grism survey simulations

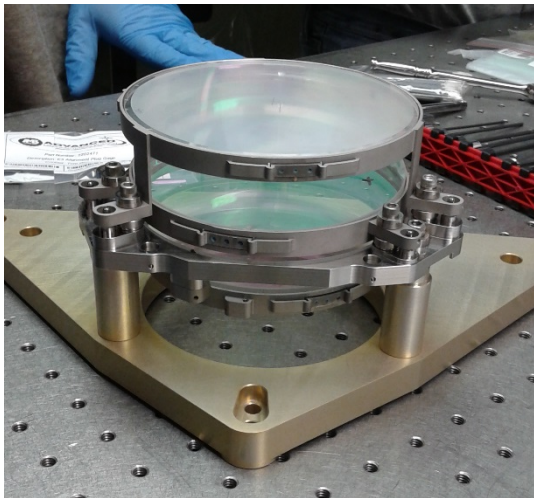
Below: microlensing survey simulation





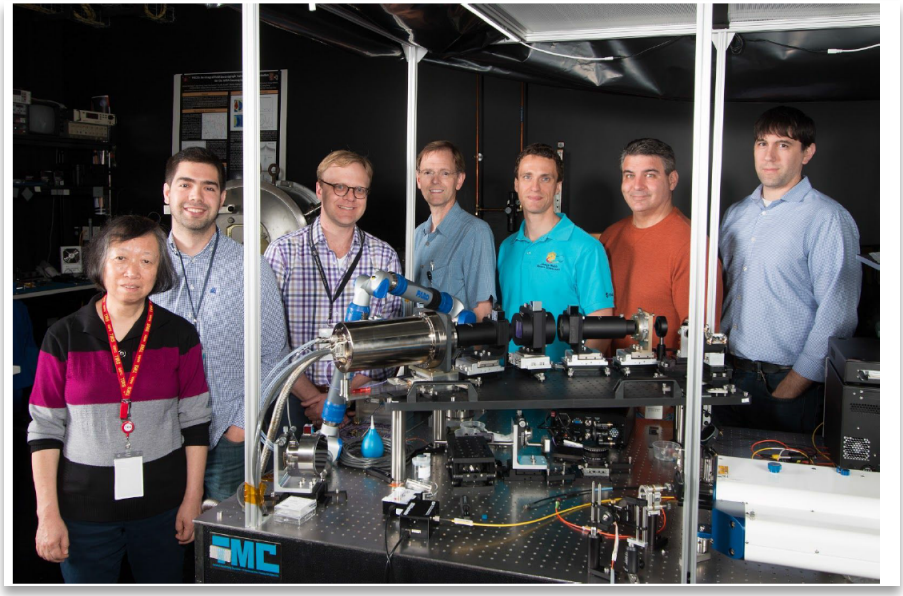
Warm Jupiter at 2 AU from G2 star at 3 pc + 10 zodi dust structure
Coronagraph in Shaped pupil “disk mode” (6 - 20 λ/D)

Instrument Prototyping

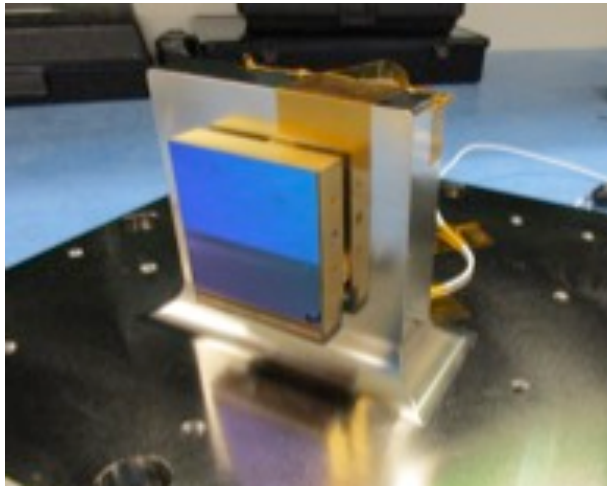


Assembled Grism Prototype

Coronagraph Integral Field Spectrometer Prototype



H4RG in vibration test



Key Points

- WFIRST Cost control processes established
- Technology development program completed
- Trade studies improving performance & simplifying
- Mission concept maturing – on track for concept review July 2017
- Telescope assessment results positive
- Instrument prototyping progressing
- Science simulation & science center work underway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DISCUSSION


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Backup

WFIRST Context

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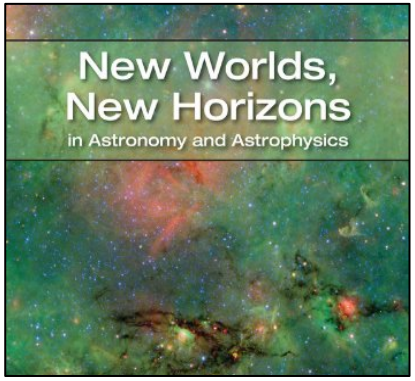
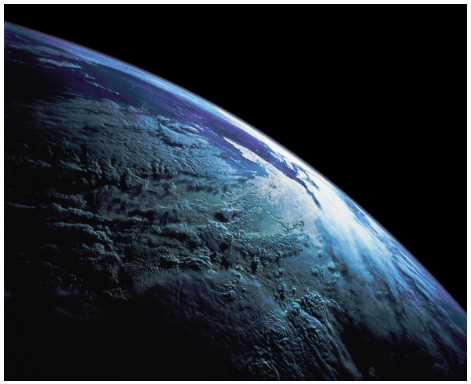
Hits 5/6 NASA Strategic Goals

Addresses all 3 APS performance goals

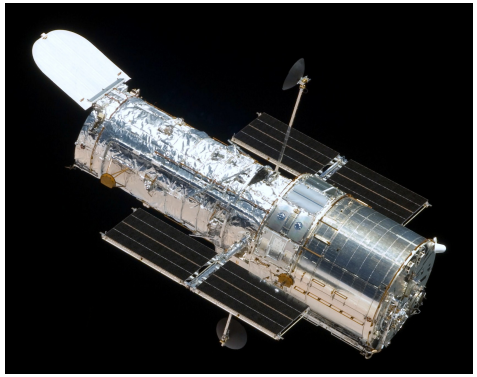
#1 Priority of Astro Decadal Survey



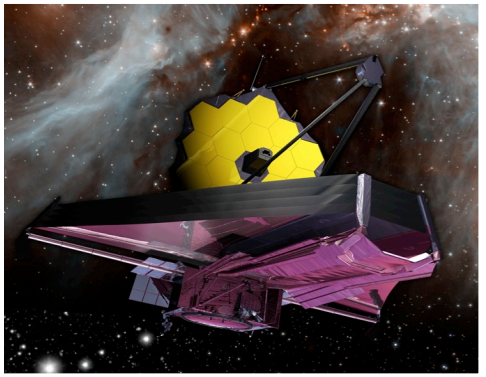
Brings the Universe to STEM education



Foundation for discovering Earth-like planets



Hubble's clarity over 10% of the sky



Complements and enhances JWST science

Starshade Compatibility Hardware Requirements

- Spacecraft accommodations:
  - Dedicated S-band transponder and low-gain antenna for SC-to-SC communications and ranging
  - Starshade acquisition camera to enable coarse acquisition of the Starshade
- CGI Accommodations:
  - 3 additional masks in the Focal Plane Mask wheel
  - 3 additional filters in the Filter wheel (might reduce to 2 new filters)
  - Existing LOWFS filter replaced by a dual filter component in LOWFS beam train
  - Lateral sensing and control functions using direct imager and LOWFS
    - Coding/implementation of these functions being deferred until after Decadal outcome
  - IFS designed to 20% or 21% bandpass
  - Ability to protect detectors from thruster plume scattered starlight
    - Currently investigating whether shutter mechanism is required